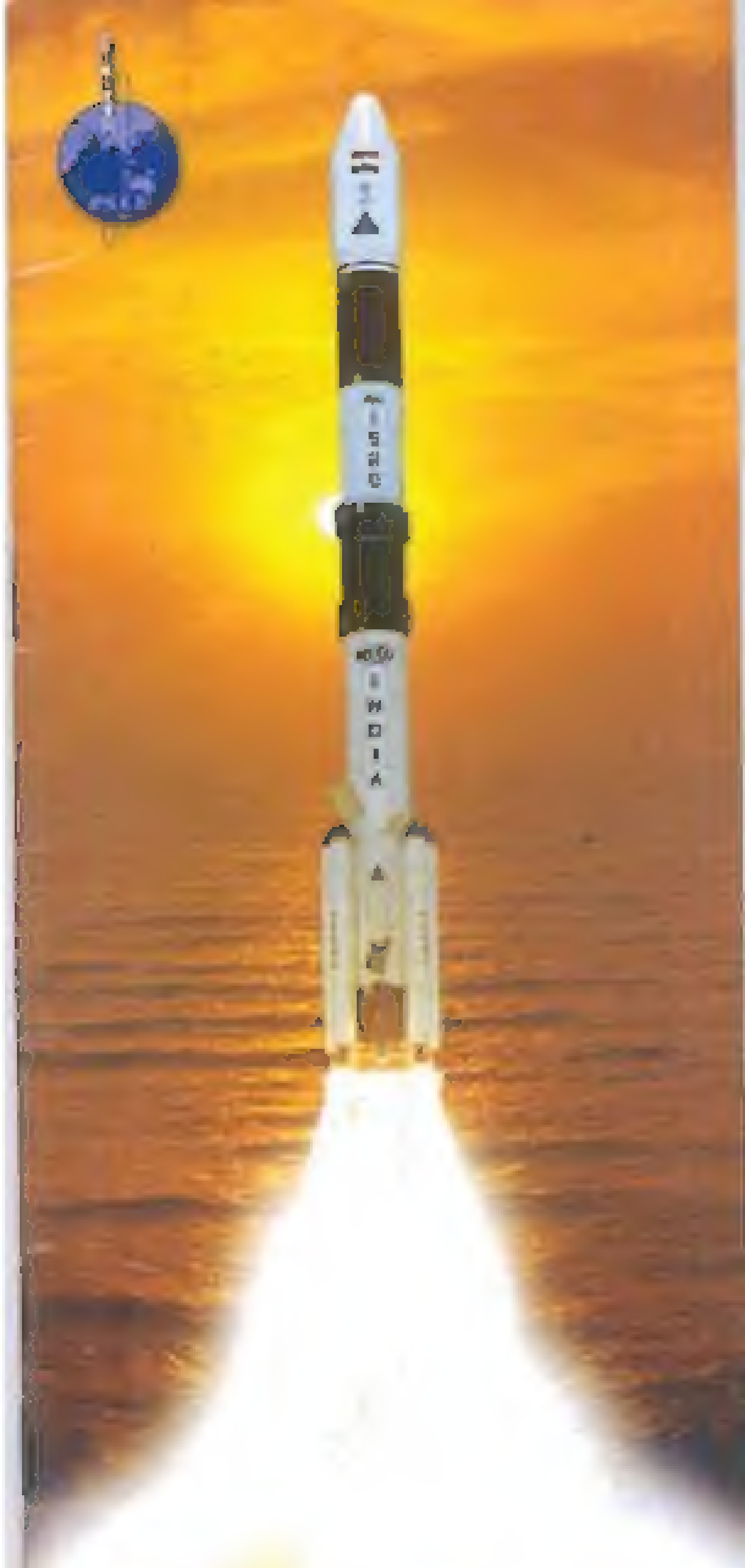


PSLV C4 - METSAT MISSION

INDIAN SPACE RESEARCH ORGANISATION

IRS-1D

...29 September 1997

PSLV-C1 take-off

IRS - P4, KITSAT-3, DLR TUBSAT

...26 May 1999

PSLV-C2 take-off

TES, PROBA, BIRD

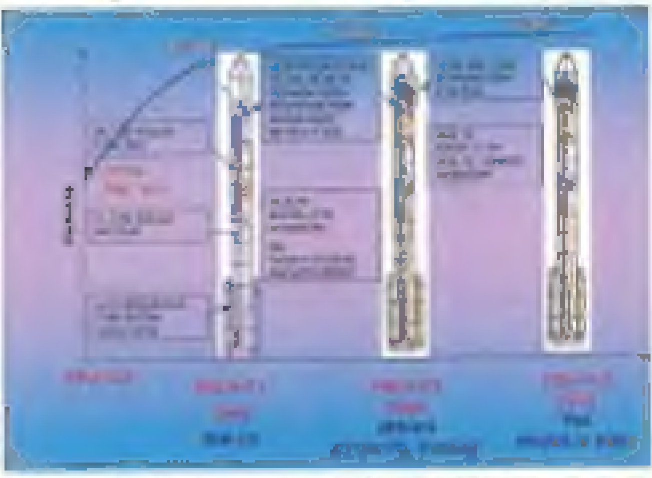
...22 October 2001

PSLV-C3 take-off

PSLV CONTINUATION PROGRAMME

Polar Satellite Launch Vehicle was developed to primarily achieve the indigenous capability to launch remote sensing satellites of 1000 kg class in Sunsynchronous Polar Orbits.

Through three development and three operational flights, PSLV has established itself as a reliable launch vehicle to meet the above requirement. The basic vehicle configuration remains unchanged from PSLV-D1 to C3. In PSLV-C1, major changes were introduced in the propulsion modules to enhance the payload capability. The main propulsion modules currently are six numbers of PSOM motors, S139 solid booster, PL40 liquid second stage, PS3/HPS3 solid third stage and PS4 liquid stage.



S139 and PL40 stages were introduced in PSLV-C1 mission to meet the minimum operational spacecraft mass requirement of IRS-1D. The firing sequence of PSOMs was changed from two motors ignited in ground to four to enhance the payload capability. Launch of PSLV-C1 took place in September 1997, which put IRS-1D weighing 1200 kg into orbit.

In PSLV-C2, multi-satellite launch capability was demonstrated in SSPO mission, where three satellites viz., primary satellite IRS-P4 (Oceansat), Kitsat-3 & DLR-Tubsat were injected. Changes were made in the Equipment Bay (EB) to accommodate auxiliary satellites in PSLV as a permanent feature. PSLV-C2 was the first mission in which a foreign satellite was launched from Indian soil.

In PSLV-C3, multi-satellite multi-orbit mission capability was demonstrated. Three satellites viz., primary satellite TES, PROBA from Belgium and BIRD from Germany were launched. Both TES and BIRD were put into a sunsynchronous polar orbit of 568 km and PROBA was injected to a higher elliptical orbit of 568 x 638 km. The orbit raise was achieved by firing the yaw RCS thrusters of PS4 in off-modulated mode.

In both PSLV-C2 & C3 new mission modes, interfaces and systems involving auxiliary satellites were developed and proven. The separation and orientation sequence for multi-satellite deployment, algorithms for orbit raising, data storage and delayed telemetry systems, new separation systems for small satellites are few of them.

PSLV-C4 is a Geosynchronous Transfer Orbit (GTO) mission to inject Metsat weighing 1050 kg into a 200 x 36000 km orbit.

Further continuation programme of PSLV is approved to meet ISRO's satellite launch requirements as well as to cater to the commercial opportunities. Action taken for vehicle realization up to PSLV-C9 and launch manifest up to C15 and corresponding missions identified.

In the continuation launches it is proposed to enhance the PSLV capability further to 2 ton in SSPO. A new compact version of PS4 called L1 stage is being developed to provide more usable payload volume inside the heat shield compartment. To mount two main satellites a Dual Launch Adaptor (DLA) is also being developed. Both these systems will be available from PSLV-C6 onwards.

PSLV Launch Manifest

The launch profile beyond PSLV-C4 is given below:

Mission & Schedule	Orbit and payload
PSLV-C5 (2003)	817 km SSO Resourcesat, 1350 kg
PSLV-C6 (2003)	618 km SSO Cartosat-1, 1450 kg
PSLV-C7 (2004)	630 km SSO Cartosat-2+SRE, 1200 kg
PSLV-C8 (2004)	GTO Metsat-2
PSLV-C9 (2005)	600 km SSO Elsat, 1400 kg
PSLV-C10 (2005)	867 km 20 deg Megha-tropiques + copassenger 1200 kg
PSLV-C11 (2006)	600 km LEO Astrosat, 1500 kg
PSLV-C12 (2006)	817 km SSO Resourcesat-2, 1400 kg
PSLV-C13 (2007)	GTO Metsat-3
PSLV-C14 (2007)	SSO 1500 kg
PSLV-C15 (2008)	720 km SSO Oceansat-2

PSLV-C4 MISSION OVERVIEW

PSLV-C4 will inject Metsat spacecraft weighing 1050 kg in a Geosynchronous Transfer Orbit (GTO) in direct ascent mode from SHAR. Mission Specifications are as follows.

Orbit specification

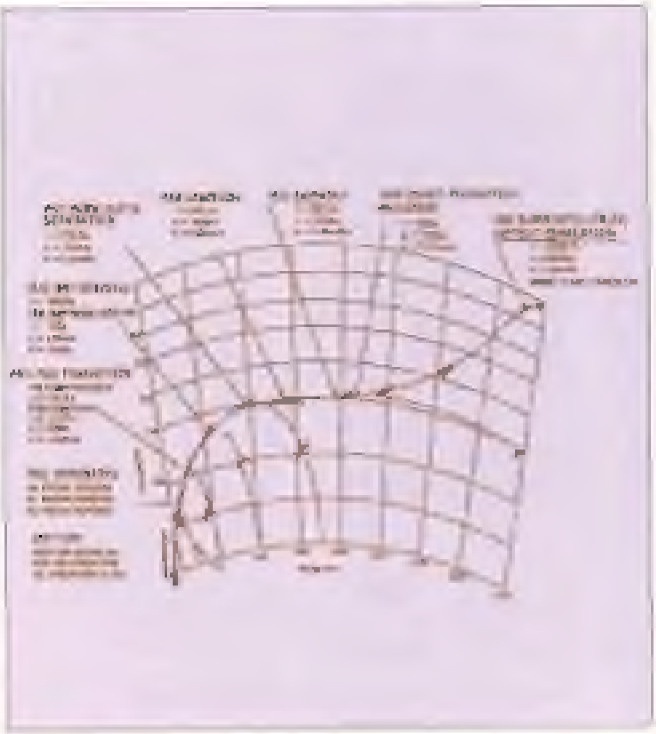
Perigee altitude	:	>180 km
Apogee altitude	:	36000 km
Inclination	:	17.8 deg
Argument of perigee	:	179 deg

The launch azimuth for PSLV-C4 is set at 102 deg as compared to 140 deg for C3. Since the launch pad azimuth is 135 deg, it requires a roll manoeuvre to align the flight path immediately after lift off. In PS1regime, open loop steering programme is designed for the mean wind biased condition to relieve the loads on vehicle. Guidance initiated command cut-off is planned for PS2 stage to meet spent stage impact constraints with reserve propellants as guidance margin. Command cut-off also ensures benign dynamic environment for the satellite.

The heat shield separation is delayed compared to PSLV-C3. However the altitude of separation is maintained for nominal performance as 115 km to meet the heat flux constraints for spacecraft. The closed loop guidance is initiated at 14.8 s from PS2 ignition. During PS2 regime Flat Earth (FE) guidance scheme is employed. The HPS3 burn duration is longer and it also achieves near orbital velocity conditions at burn out. A VG guidance scheme with terminal pitch rate algorithm to contain PS3 impact in safe zone is implemented.

During the combined coast of PS3 & PS4 stages, prediction of coast duration is done and the perigee is decided onboard based on the vehicle performance. This scheme is implemented to ensure the optimality of payload with the constraint of impact of spent PS3. During PS4 regime, a FE guidance scheme with injection guidance to control argument and perigee is implemented and spacecraft injected after PS4 cut-off.

Metsat mounting orientation in PSLV is designed to ensure that VHRR cooler is not facing sun during powered flight regime.



Typical flight sequence

This condition is to be ensured immediately after separation before the ground stations acquire the spacecraft. Hence, before Metsat separation, PS4 stage with Metsat is re-oriented in both pitch and roll directions to keep the VHRR cooler away from sun and also orient the solar panel to ensure minimum power generation in case of non deployment.

A dry loop command for Metsat is issued 15 s before separation by PSLV. Metsat is separated in attitude hold mode to contain the separation rates. The springs in the separation system are tuned to get the least separation disturbance considering the lateral CG offset of Metsat.

After Metsat separation, the stage is manoeuvred in yaw by 60 deg and the passivation function is initiated by sequentially opening the tank ullage to the ambient by firing pyro valves. PS4 will be attitude stabilized with yaw control thrusters firing in off-modulated mode during this phase.

The mission design of PSLV-C4 is aimed at meeting two major constraints of maximizing the payload capability and managing the impact of the spent stages, especially the PS3 stage within safe corridor.

PS4 orientation sequence for spacecraft separation and passivation

METSAT

METSAT is a meteorological spacecraft designed for launch by PSLV. The spacecraft configuration is basically derived from INSAT heritage. Till now, the communication and meteorological capability were provided by the INSATs. Metsat is conceived considering the urgent need of ensuring continuity of meteorological services in a cost effective manner. Metsat is configured for seven years of mission life.

Metsat deployed view

The payloads in Metsat are the following:

A VHRR package containing:

- A three-band Very High Resolution Radiometer (VHRR) payload providing imageries in Visible, Water Vapor (WV) and Thermal Infra Red (TIR) bands.
- An Electro Optics Module (EOM) housing the scan mechanism, optics and passive radiative cooler assemblies, camera electronics for signal processing and scan mechanisms drive electronics.
- The payload also includes data transmitter packages housing the BPSK modulator, up-converter and transmitter.

The VHRR has the heritage from INSAT. However certain modifications are made for performance improvements & reliability enhancement.

Weather Data Relay Transponder (DRT) is the second payload for collection data from unattended weather data collection platforms through out India and transmits to a central facility. DRT data along with VHRR data is used for weather forecast.

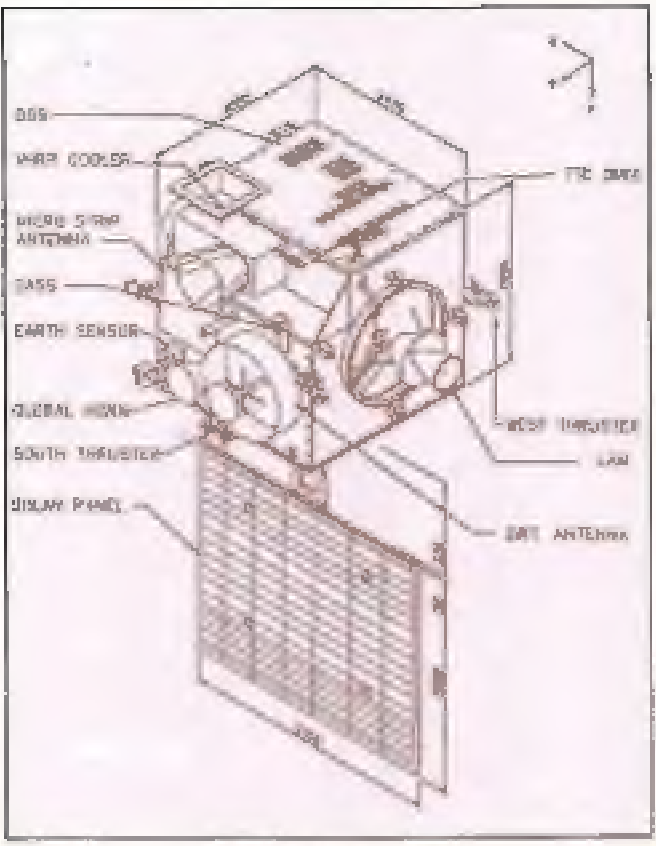
The spacecraft structure is derived of the I-2000/I-1500 bus. The majority of the structure is made of aluminium honeycomb with CFRP face skin except for elements that have electrical and thermal constraints.

For orbit raising operations the 440 N Liquid Apogee Motor (LAM) is used, which is already flight proven. The propulsion system is based on pressure fed bi-propellant system. Two propellant tanks of 390 litres capacity is used and one Kevlar wound Titanium lined gas bottle is used for pressurisation. Twelve numbers of 22 N control thrusters are used for attitude manoeuvres, which are mounted on three faces.

Metsat during testing

The spacecraft has only one solar panel of 2.15 x 1.85 m size with weight optimised structural elements. The solar cell is based on GaAs/Ge technology. Solar panel is deployed immediately after the deployment in the transfer orbit itself unlike INSATs. The SADA slip rings and drive mechanism are modified to meet the power transfer and drive requirements and is mass optimised. The LAM firing is carried out with panel deployed configuration. The power bus is based on a single Nickel-Cadmium battery of 18AH capacity.

Metsat, unlike INSATs is not provided with solar sail and boom. Two body mounted magnetic torquers carry out the solar pressure torque compensation.



Identification of systems on Metsat

Metsat is a momentum biased, three axis body stabilized spacecraft with a pointing accuracy of ± 0.2 deg in pitch and roll axes and ± 0.4 deg in yaw axis. During VHRR imaging periods, the control and house keeping functions are inhibited to get better line to line scanning accuracy.

The Attitude and Orbital Control System (AOCS) hardware consists of 68 Nm momentum wheel with 25 Nm transfer momentum wheel. Sensor devices used in the spacecraft are high accuracy Digital Sun Sensor (DSS), eight coarse analogue sun sensors and earth sensor. The three axis inertial reference unit with the magnetic torquers and AOCS thrusters constitute the total system.

The spacecraft separation occurs in three axis stabilized mode with sun at 45 deg to the south side of the spacecraft. A dry loop command for propellant line venting is issued by PSLV 15s prior to separation. Twenty two seconds from separation the solar panel gets deployed over a time of 7s. The thrusters commence firing to put the spacecraft in east sun pointing mode at 30s. The ground station at Lake Cowichan at Canada acquires Metsat after about 45 minutes from separation and MCF will receive the data from them. The gyro calibration is

carried out prior to apogee crossing. As per the nominal mission plan, the orbit raising and circularization is carried out by firing the LAM in the 2nd, 4th and 6th apogee crossings. Metsat is proposed to be co-located with INSAT-3C at 74 deg East longitude.

NEW ELEMENTS & CHANGES IN C4 VEHICLE

In PSLV-C4, the payload capability is enhanced by improving the upper stages performance and by optimization of the inert masses of the upper stage structures/elements.

The third stage solid motor, PS3 is replaced by the optimised high performance stage (HPS3). In PS4, additional 500 kg propellant is loaded by extending the propellant tank. The inert mass reduction is achieved in the upper stages through introduction of the following elements.

- Composite PS4 stage structure (IS3/4).
- Composite wound Titanium gas bottles in PS4.
- Resins Mk-3 package.
- Composite elements for PS4 RCS cowlings.
- Mass reduction in EB by deleting measurements and associated packages.
- Introduction of mini version packages in EB
- SRRT is replaced by mini SBT.
- Introduction of miniature PS4 control electronics package.
- Auxiliary satellite interfaces removed.

New systems introduced/changes specifically required in PSLV-C4 are the following:

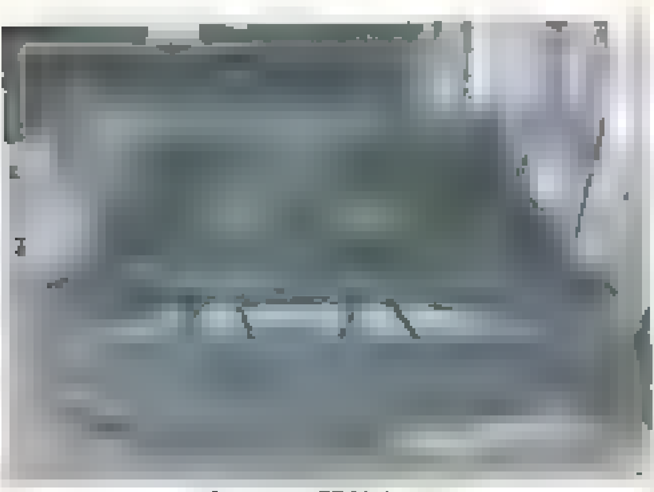
- New payload adaptor (PLA-Y2) of 1m length for accommodating Metsat.
- Number of Helium gas bottles in PS4 increased to 4 from 3
- Propellant feed lines and circuits in PS4 modified for weight reduction.
- Passivation system in PS4 for expelling the energetic constituents from stage after the completion of mission.

- Destruct system in PS4 stage considering the range safety requirement as an extension to PS3 destruct system.
- RF transfer antenna for Metsat mounted in Heat Shield.
- PNC system elements modified to suit HPS3

Mission related changes are implemented to meet the GTO mission requirements.

- Launch azimuth is set at 102 deg and a roll manoeuvre after lift off.
- Flight sequence changes to meet the mission profile like:
    - Delaying of Heat shield separation.
    - PS2 cut-off based on guidance command.
    - Reorientation manoeuvre before spacecraft separation in both Pitch and Roll directions.
- Autopilot design tuned towards changes such as HPS3, L2.5 stages etc
- Modifications in rate control algorithm during satellite separation sequence.
- Guidance schemes in various flight regimes altered to meet GTO mission.
- Changes in onboard softwares to meet the mission requirements.

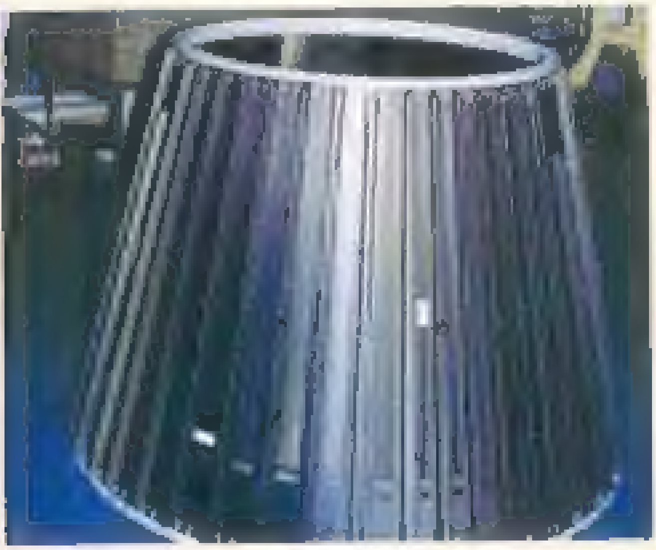
All the changes implemented in PSLV-C4 have gone through rigorous reviews and testing. The static testing of HPS3, long duration firing of PS4 engine, structural testing and characterisation of new composite structures and functional testing of other new elements are completed. All the changes have been documented.



Composite IS3/4 structure

L2.5 stage with Equipment Bay

HPS3 motor



CFRP PLA-V2

In the mission software side, extensive verification and validation has been undertaken. Stress tests, detailed walk through and validation have established robustness of software.

HIGH PERFORMANCE PS3 MOTOR

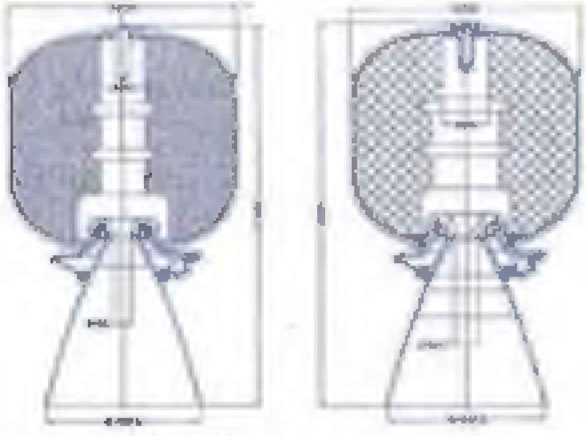
High performance PS3 (HPS3) motor is an optimised version motor, which is comparable in performance and mass ratio to contemporary motors of its class. This is developed for enhancing the payload capability of PSLV.

Construction features

- Optimised composite motor case.
- Optimised insulation.
- Reduced throat, increased area ratio, lighter nozzle.
- Flex nozzle with 2 deg actuation.
- PSOM propellant composition with enhanced loading of 300 kg.
- 100 kg inert mass reduction.

Performance characteristics

- 5 s increase in Isp (299s).
- Improved mass ratio.
- Low burn rate propellant and increased burn duration
- Payload gain through inert mass reduction, propellant increase and higher Isp.



Comparison of HPS3 & PS3

Second static test of HPS3

Two development tests on HPS3 are completed successfully and one more confirmatory test is planned.

LAUNCH RANGE FACILITIES

The final vehicle integration and checkout, spacecraft preparation and fuelling, count down and launch are carried out at the launch base at Shriharikota Range (SHAR). Exclusive facilities are created for the launch support for PSLV and GSLV by SHAR and are fully operational. The facilities for integration & checkout, propellant servicing, Mobile Service Tower, Mission and Launch control center and Range instrumentation and support facilities are revalidated for this mission after T&E. No change in integration procedures is made from PSLV-C3.

TTC NETWORK FOR PSLV-C4

TTC network provides the tracking support for vehicle and acquire telemetry data till 200 seconds after PS4 thrust cut-off. ISTRAC Ground Stations at SHAR-I (Main), SHAR-II (Redundant) are identified as launch base stations and Port Blair, Brunei and Biak are identified as down range ground stations.

These ground stations are equipped with real time data processing and transmissions of stripped data to Mission Control Center (MCC) for Range Safety and monitoring of vehicle parameters. The transmission of data is linked with dedicated satellite communication link and also redundant circuits through alternate terrestrial links.

Biak ground station provides near real time Preliminary Orbit Determination (POD). Also, this station supports Metsat telemetry data reception and transmission to MCF-Hassan and in addition to telecommand support. MCF at Hassan supports Metsat telemetry and command data. External ground station like Lake Cowachin is used for Metsat support after 45 minutes of injection into orbit.

Bangalore ground station supports for TM data acquisition and logging. Trivandrum ground station is interfaced with SHAR to receive specialist display data and sequence of events in mission.

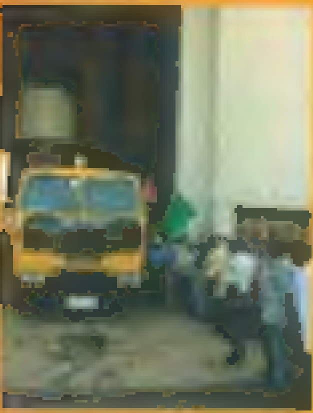
As in earlier flights, telecommand system is used for sending flight termination command from Range Safety Officer (RSO) console for range and flight safety in case of deviation of the vehicle from safe trajectory.

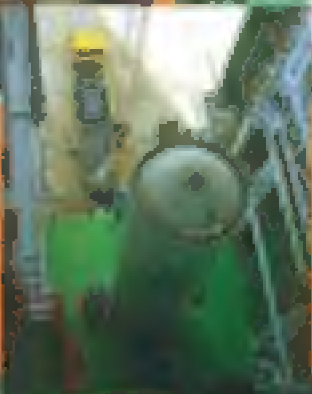
SHAR Range supports PSLV-C4/Metsat mission by three different Real Time Systems for Range Safety Display (RS), Specialist Display (SDS) and MCC displays.

For PSLV-C4, SHAR based Radars viz., PCMC1, PCMC2 & Radar-2 will provide tracking data in conjunction with two onboard C-band transponders for Range Safety real time system in addition to skin mode tracking data by Radar-3.

LAUNCH CAMPAIGN PICTURES

Flag-off of core base shroud from VPMC





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